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Prospective chemistry teachers' perceptions of their profession: the state of the art in Slovenia and Finland

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Abstract: The main purpose of this paper is to present Slovenian and Finnish prospective chemistry teachers' perceptions of their future profession, especially with regard to their understanding of the role of the triple nature of chemical concepts (macro, submicro and symbolic) and their representations in chemistry learning. A total of 19 prospective teachers (10 Slovenian, 9 Finnish) at master's level in chemical education participated in the research. The prospective teachers' opinions were gathered using an electronic questionnaire comprising six open-ended questions. The study revealed many parallels between Slovenian and Finnish prospective chemistry teachers' perceptions of their future profession and their understanding of the role of the triple nature of chemical concepts, especially particle representations, in chemistry learning. The majority of the prospective teachers from both countries believe that personal characteristics are the most important attribute of a successful chemistry teacher. Thus, they highly value teachers' enthusiasm for teaching and the use of contemporary teaching approaches in chemistry. The prospective teachers displayed an adequate understanding of the role of the triple nature of chemical concepts (*i.e.*, particle representations) in the planning and implementation of a specific chemistry lesson.

Keywords: attributes of a chemistry teacher; chemistry teacher profession; triple nature of chemical concepts; particle representations.

INTRODUCTION

The examination of the characteristics of a good teacher dates back to Ancient Greece. At that time, good teachers were primarily described as mentors fulfilling career and psychosocial functions for their "protégés".¹ The career-oriented activities helped protégés to "learn the ropes", while psychosocial-oriented activities, based on trust, intimacy and interpersonal bonds, facilitated the

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professional and personal growth, identity, self-worth and self-efficacy.² Thus, teachers maintained a balance between the academic and (inter)personal dimensions of educational practice.³

Research confirms that contemporary teachers, too, influence both students' learning and their personal development. It has been suggested that students' relationships with their teachers are two-fold: on the professional level, teachers are important for the encouraging of interest, curiosity, and motivation,^{3,4} as well as providing the learning support and feedback on the academic performance,^{5,6} while, on the personal level, they affect the students' sense of identity.^{4,7} Since teachers have a major impact on both students' academic and personal development,³ it is suggested that the establishment and the maintenance of a positive teacher-student relationship, including both academic and personal dimensions, should become a primary goal for all educational institutions.

To establish these aspects of chemistry lessons, teachers should have positive attitudes towards science. Baron and Byrne⁸ define attitudes as general considerations of people about themselves, about other people, and about objects. Teacher's personal attitudes toward any aspect of practice in their profession influence their pattern of behaviour.

The concept of attitudes towards science (including chemistry) is a conglomerate of several components. According to a review by Osborne,⁹ the following are the most important: 1) the perception of the science teacher, 2) the anxiety towards science, 3) the value of science, 4) the self-esteem regarding science, 5) the motivation for science, 6) the attitudes of peers towards science, 7) the joy with science, 8) the nature of the classroom learning environment, 9) the achievement in science, 10) the fear of failure in taking a science course, 11) the preference towards certain learning approaches and 12) the enrolment in science courses in school. Koballa *et al.*¹⁰ concluded that beliefs influence all kinds of interactions between teachers and pupils, and described teachers' beliefs about teaching and learning as always including aspects of beliefs exclusive to their discipline or subject. Bandura considered beliefs to be the best indicators of why a person behaves, handles information, and makes decisions in a certain way.¹¹ These beliefs then dictate decisions related to planning the learning experiences for their students, and may influence students' learning opportunities.¹² In addition, teachers' beliefs and concerns influence decisions about which teaching practices to use in their classrooms.¹³ It can be also emphasised that if teachers and pre-service teachers have positive attitudes toward chemistry/science, they may positively develop their students' attitudes towards chemistry science.¹⁴ Markic and Eilks concluded in their study of pre-service chemistry teachers beliefs about chemistry teaching, that the student teachers enter university education with preconceptions most probably influenced by their personal experiences in traditional chemistry classes they experienced during their primary and

secondary education.¹⁵ Attitudes of pre-service chemistry teachers towards chemistry influence their decisions made during university education. They develop their competences according to beliefs and when they start teaching they implement these competences in their classes. For that reason, it is important for them to learn how to use up to date and adequate teaching approaches in the classroom, and during this process in the pre-service education we can influence their attitudes towards chemistry teaching. With regard to the role of chemistry teachers in the development of students' perceptions of chemistry as a school subject, it was found that, for the majority of students, knowing that chemistry teachers are available to offer help was the most important factor in their preference for chemistry.¹⁶ In addition to teachers' support to students during chemistry classes, the students' interest in learning chemistry is also important. In this regard, students showed the lowest level of intrinsic motivation for the submicroscopic and symbolic levels of the chemical concept.¹⁷ For many years, chemistry educators and researchers have explored how the triple nature of chemical concepts (macro, submicro, symbolic), TNCC helps students to develop their conceptual understanding of chemical phenomena. With reference to the triangle of the TNCC, which was introduced by Johnstone,¹⁸ some other authors^{17,19-21} have tried to develop different models that illustrate the connections between the TNCC.

Research^{19,22-27} also shows that students have many difficulties in understanding the submicro and symbolic levels of chemical concepts. The difficulty of teaching and learning chemistry lies in the complexity of chemistry itself.²⁸ Chemical concepts can be explained at three levels: the macroscopic (observable) and submicroscopic levels (particulate, the most abstract level) are real, but the symbolic level (symbols, formulae, equations) concerns the representation of reality.²⁹ Representations of the submicro-level (schematic representations of particles) are also called submicro-representations (SMRs).³⁰⁻³² Teachers and authors of the teaching material should take this complexity of the TNCC into account and should develop educational strategies integrating the visualisation methods (SMRs) and the appropriate language use (strict use of the name of particles when needed) in social situations (*e.g.*, collaborative learning).^{24,33} In this way, students are able to develop the mental models of chemical concepts with a low level of misconceptions at the macro, submicro and symbolic levels.^{31,34-36} However, there are also specific student attributes that can influence TNCC learning.²⁵ Students' ability to interpret the TNCC's rather complex system of representing the abstract chemical concepts is also related to the students' systems thinking skills.³⁷⁻³⁹ These skills should be developed and assessed during chemistry lessons, as proposed by Hrin *et al.*,⁴¹ who suggested the specific assessment tools using systemic synthesis questions (SSynQs) in organic chem-

istry to evaluate the most complex dimension of systems thinking amongst secondary school students.

The research in science education, in the last two decades, has therefore emphasised the use of the different educational strategies to overcome the gap between the three levels of chemical concepts.^{25,30,41–43} The basis of the correct comprehension of chemical concepts is the understanding of the structure of matter. It is therefore recommended that the teaching of science phenomena to students aged 10–12 years should originate in the macroscopic observations and gradually continue to particle interaction explanations; finally, these explanations should be translated into symbolic representations.⁴⁴

Numerous misconceptions of the TNCC have been identified and described in the literature.^{25,26,45} These misconceptions occur throughout the chemistry content, from substances and mixtures, through solutions and chemical reactions, to electrolyte chemistry, *etc.*, as well as in organic and biochemistry chemistry. Research has identified various misconceptions regarding the basic particle composition of matter; for example, students represent matter with a continuous and static model,⁴⁶ or they attribute the macroscopic characteristics of matter to its particles.⁴⁷ They also think that particles change size or composition when the state of matter changes.⁴⁸ Slovenian secondary school students (16-year-olds) also express specific misconceptions about this topic; they think that the distances between particles in a liquid state are much greater than in a solid state (29.2 % of students), or that particles are arranged in a liquid state the same way as they are in a solid state (26.7 % of students).¹⁷

Similar misconceptions can be identified in solution chemistry. Students have misconceptions on the macro level (*e.g.*, solute disappears while dissolving in the solvent, a new substance is formed while dissolving, *etc.*) or on the sub-micro-level.⁴⁷ In Slovenia, 43 % of 16-year-old students express some kind of misconception of solution chemistry at the submicro level (*e.g.*, distances between particles, arrangement of particles, *etc.*).²⁷ Another basic area in which misconceptions of the TNCC have been identified are chemical reactions. Writing and reading SMRs is a useful tool for the identified misconceptions of chemical reactions in the TNCC while translating SMRs to symbolic chemical language. Research shows that similar misconceptions occur internationally, and that integrating the TNCC into teaching and learning chemistry can diminish the development of misconceptions of the chemical concepts and can have an effect on the misconceptions already established.^{17,49}

METHODOLOGY

Research problem and research questions

Taking into account the importance of the TNCC for developing an adequate understanding of chemical phenomena at all levels of education, and considering the fact that competent teachers have a basic role in stimulating student learning, the following research problem was

developed. When thinking about the future of chemistry teaching at schools, it is important to emphasise that the pre-service chemistry teachers should be educated in a way that facilitates their development into competent in-service teachers. In order to provide the stimulating learning environment and the educational process at the university level for prospective teachers, we need the information about the pre-service teachers' beliefs and attitudes towards their future profession and also the insight into their understanding of how the triple nature of chemical concepts should be integrated into teaching of chemistry. TIMSS 2011⁵⁰ showed that Slovenian and Finnish eighth-graders achieve better results in the chemistry domain, than the eighth-graders from other European countries. This result could be linked to the many years of effort in teacher education and research in the field of chemical education, which has a long tradition in both countries. Slovenian 15-year-old students achieved the best results in science TIMSS 2015⁵¹ in Europe (Finland did not participate), while PISA 2015⁵² results confirm that the achievements of Finnish, Estonian and Slovenian students are among the highest in the scientific literacy domain. It is therefore interesting to recognise patterns in Finnish and Slovenian prospective teachers' profiles with regard to their views on the chemistry teaching profession (e.g., professional orientation, chemistry teachers' characteristics, the role of the TNCC in chemistry teaching and learning, chemistry teachers' awareness of and opinions about misconceptions of the TNCC), so that innovative and effective educational strategies in pre-service and in-service chemistry teacher education can be developed and implemented.

The following research questions were formulated:

1. Do Slovenian and Finnish prospective chemistry teachers differ in the main reasons for their decision to become a chemistry teacher?
2. What do prospective chemistry teachers in Slovenia and Finland believe are the most important attributes of a successful chemistry teacher?
3. Do Slovenian and Finnish prospective chemistry teachers differ in their opinions about the importance of TNCC implementations in chemistry teaching and learning?
4. Do Slovenian and Finnish prospective chemistry teachers have similar beliefs about the most common student misconceptions of the TNCC?

Participants

Nine Finnish (six female, three male) and ten Slovenian (nine female, one male) prospective chemistry teachers participated in the study, all of whom were enrolled in a second-cycle programme (master's) in chemistry education. Prior to the enrolment in master's study, both groups of students had finished first-cycle programmes in chemistry or two-subject teacher programmes (e.g., chemistry and biology; chemistry and physics; chemistry and home economics; chemistry and mathematics). Slovenian pre-service chemistry teachers participated in the courses (e.g. Chemistry didactics I and II, Experimental and project work)⁵³ where they were acquainted with the topics related to triple nature of chemical concepts and misconceptions in this context that students aged 11 to 18 can develop during their chemical education. The misconceptions topics regarding submicroscopic level of chemical concepts that were discussed in more details are: chemical reaction, solution chemistry, pure substances and mixtures, electrolyte chemistry. Similarly, Finnish pre-service chemistry teachers were acquainted with these topics in their courses (e.g., the central fields of chemistry education) where they learned how to teach the main concepts and phenomena on the base of research concerning misconceptions. The focus in Finnish program is to educate student-centred chemistry teachers who understands different kind of students' thinking about the chemistry concepts and phenomena and can catalyse their learning processes by following students' development.⁵⁴ The students participated in the study voluntarily and anonymously. On average, the

Finnish prospective chemistry teachers participating in the study were older than their Slovenian counterparts (see Figs. 1 and 2).

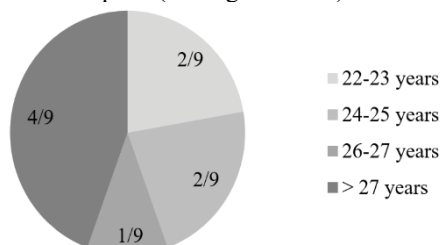


Fig. 1. Age of the Finnish prospective chemistry teachers.

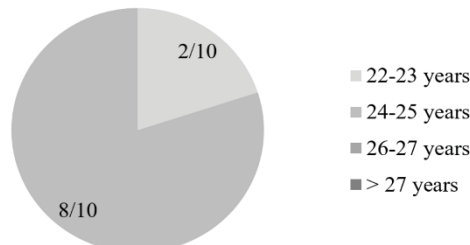


Fig. 2. Age of the Slovenian prospective chemistry teachers.

Instrument

The data was gathered with the application of an open-ended questionnaire in English comprising of six questions about prospective teachers' views on their future profession, their awareness of applications of the TNCC in their teaching, and basic misconceptions that students can possess about the TNCC. The questions were: 1) Why have you decided to become a chemistry teacher? What were the main reasons for this decision? 2) What do you believe are the most important characteristics of a successful chemistry teacher in basic chemistry education (students aged 13–15)? 3) Do you believe it makes sense to integrate particle representations (*e.g.*, models, SMRs) into chemistry teaching and learning (students aged 13–15)? If so, why? 4) In to your opinion, what is the role of SMRs in teaching and learning chemistry in basic chemistry education (students aged 13–15)? 5) In your opinion, what are students' (aged 13–15) most common misconceptions related to the TNCC that need to be addressed when using SMRs in teaching chemistry? 6) It was found that students' misconceptions of chemical concepts can sometimes be developed due to SMRs in chemistry textbooks. In your opinion, what possible misconceptions, if any, could be developed by students (aged 13–15) when learning dissolving using the SMR in Fig. 3?

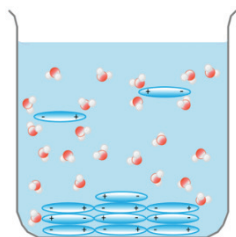


Fig. 3. A sample of an SMR from a Slovenian chemistry textbook (for the purpose of the article SMR is presented in black & white; the original SMR in the textbook is printed in colour).

The SMR presented in Fig. 3, which was used in the last question of the questionnaire, is an example of an SMR presented in one of the Slovenian textbooks for 8th grade basic education chemistry (13-year-olds).

Research design

The questionnaire in English was administered to the prospective teachers by e-mail and collected electronically. The prospective teachers' answers to the open-ended questions in English in the questionnaire were categorised regarding natural units of meaning. In each set of answers to the questions, a set of context-important words (codes) were determined. Using

this approach, the answers of the Finnish prospective chemistry teachers became comparable to the answers of their Slovenian counterparts. The answers were divided into separate categories consisting of the same or very similar codes. In order to assure high reliability of categorisation, two researchers (two of the authors of this paper) independently evaluated all of the transcriptions using the code table a second time, approximately one month after the first analysis, resulting in 95 % of repeated evaluation being achieved overall. Both evaluations were subsequently contrasted at points where differences occurred and, after consideration, the researchers decided on the more appropriate evaluation.

RESULTS AND DISCUSSION

The results are presented with regard to the categorisation of certain answers in the interview in the subsequent order and with regard to the research questions.

The first research question was about Slovenian and Finnish prospective chemistry teachers' main reasons for their decision to become a chemistry teacher. They expressed their challenges in their decision to become a chemistry teacher. Their answers can be categorised in the following five categories: 1) I like chemistry very much, 2) Chemistry is a fascinating subject, 3) I like teaching and communicating about chemistry, 4) Chemistry is part of everyday life and 5) Chemistry teachers are fascinating.

As can be seen in Fig. 4, the majority of Finnish and Slovenian prospective chemistry teachers showed significant personal interest in chemistry. Some typical answers were:

“I just really liked chemistry.”

“I like natural sciences.”

“I’m interested in natural sciences.”

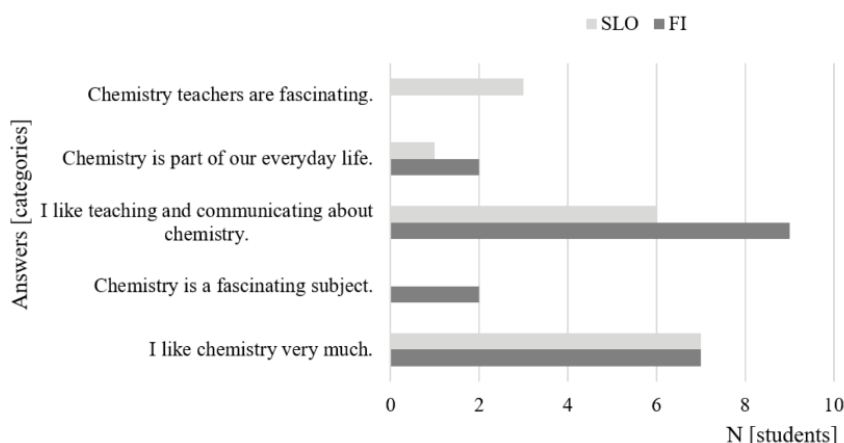


Fig. 4. Prospective chemistry teachers' answers to the question of what challenged them to decide to become a chemistry teacher.

Similarly, both groups of prospective teachers explained that they enjoy teaching chemistry and communicating about chemistry. Some typical answers were:

“I like helping people with their questions and problems in chemistry.”

“I would like to share knowledge.”

“I want my profession to be one that could potentially have a positive effect on other people’s lives.”

Prospective teachers from both Slovenia and Finland also claimed that it is challenging for them to address chemistry as a part of our everyday life in their future teaching. Some typical answers were:

“Chemistry is part of our lives.”

“Curiosity about the world.”

Finnish prospective teachers are impressed by chemistry as a fascinating subject. Some typical answers were:

“Chemistry was one of my favourite subjects in school.”

“Chemistry is a fascinating subject.”

On the other hand, some Slovenian prospective teachers are more fascinated by chemistry teachers. One of them stated:

“The chemistry teacher fascinated me in basic chemistry education.”

These findings are in line with results in other studies, which have reported that students’ relationships with their teachers are two-fold. On the professional level, teachers are important for encouraging interest, curiosity and motivation.^{3,4} Good teachers are primarily described as mentors fulfilling career and psychosocial functions for their protégés.¹ On the personal level, teachers affect students’ sense of identity^{4,7} and have a major impact on both students’ academic and personal development.³

The second research question deals with both countries’ prospective chemistry teachers’ beliefs about the most important attributes of a successful chemistry teacher. The prospective teachers are convinced that the most important characteristics of a good chemistry teacher in basic chemistry education (students aged 13–15) are as follows: 1) Personal characteristics of a chemistry teacher; 2) A chemistry teacher should be enthusiastic about chemistry; 3) A chemistry teacher should have a modern teaching approach; 4) A chemistry teacher should be interested in the students.

It can be seen from Fig. 5 that prospective chemistry teachers from both Slovenia and Finland believe that the personal characteristics of a chemistry teacher matter, and describe a good chemistry teacher as charismatic, easily approachable, inspiring and enthusiastic. Some typical answers were:

“A chemistry teacher must be charismatic.”

“A chemistry teacher has to be easily approachable.”

“Inspiring and good interaction skills.”

“Enthusiastic.”

Similarly, most of the prospective teachers from both groups also believe that a chemistry teacher has to be enthusiastic about chemistry, not just about teaching, so that students develop a positive attitude towards chemistry, a personal interest in learning chemistry and intrinsic motivation to do so. Some typical answers were:

“A chemistry teacher can have a positive influence on students’ interest in chemistry regarding the content taught.”

“Truly interested in chemistry and teaching.”

“Interested in chemistry.”

“Lively presentations.”

“Good class-reading skills.”

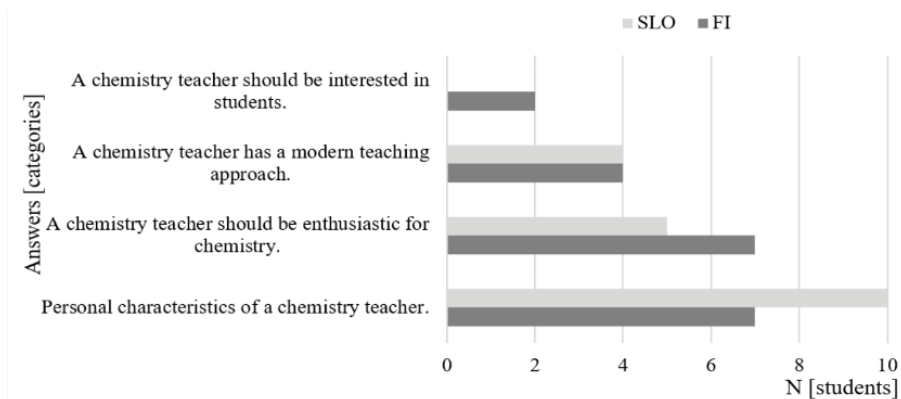


Fig. 5: Prospective chemistry teachers’ answers to the question of what do they believe are the most important characteristics of a good chemistry teacher in basic chemistry education.

Both groups of prospective teachers also believe that modern teaching approaches should be used while teaching a chemistry class. Some typical answers were:

“Using different contexts in teaching chemistry.”

“Will to improve and develop teaching.”

Only the Finnish prospective teachers pointed out that a good chemistry teacher also needs to have an interest in his/her students. Some typical answers were:

“Interested in students’ lives and care for them.”

“Genuine interest in students.”

Similar results were also obtained in other studies. According to Osborne⁹ a science teacher should value science, should motivate students for science, and should develop positive attitudes towards science, so that students can enjoy it. Teachers should develop a positive classroom learning environment and imple-

ment teaching strategies that help students to bridge the gap between the three levels of chemical concepts more easily.^{40–43} Chemistry teachers should be aware that the development of students' perceptions of chemistry as a school subject is largely dependent on teachers' attitudes towards chemistry and its teaching. It was established that, for the majority of students, knowing that help will be offered by chemistry teachers was the most important factor in their preference for chemistry;¹⁶ a good teacher should therefore help students learn chemistry in the most effective way possible.

The third research question deals with possible differences between Slovenian and Finnish prospective chemistry teachers regarding their views about the importance of TNCC implementations in chemistry teaching and learning; specifically, whether they believe that it makes sense to integrate particle representations (*e.g.*, models, SMRs) into the teaching and learning of chemistry in basic education (students aged 13–15 years). Their answers were categorised as follows: 1) It makes sense to integrate particle representations; 2) It makes no sense to integrate particle representations; 3) Not sure if it makes sense to integrate particle representations.

From Fig. 6, it is evident that the Finnish and Slovenian prospective chemistry teachers almost completely agree that it is sensible to integrate particle representations into the teaching and learning of chemistry in different levels of basic education. The answers of the two groups of students are very similar. It can be concluded that prospective chemistry teachers from both countries are familiar with recommendations that the teaching of science phenomena, even to students aged 10–12 years, should originate in macroscopic observations and gradually continue to particle interaction explanations, and that these explanations should finally be translated into symbolic representations.⁴⁴

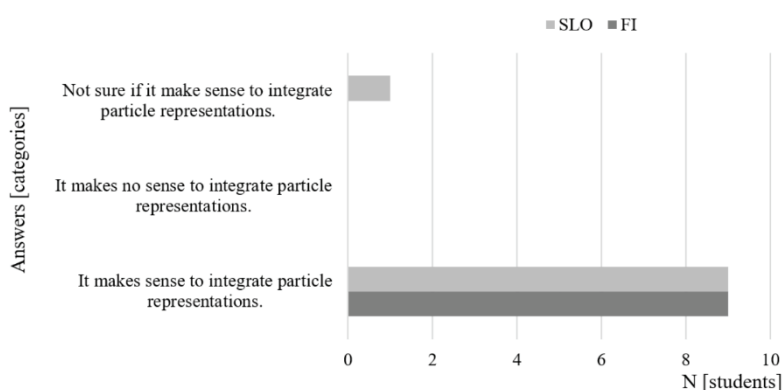


Fig. 6. Prospective chemistry teachers' answers to the question of whether they believe that it makes sense to integrate particle representations (*e.g.*, models, SMRs) into the teaching and learning of chemistry in basic chemistry education.

Furthermore, we asked the prospective chemistry teachers what they believe the role of particle representations in teaching and learning chemistry is. Their answers were assigned to the following three categories: 1) Facilitating students' understanding of the nature of science; 2) Supporting students' abstract thinking; 3) Developing students' understanding of the triple nature of chemistry.

Fig. 7 indicates that the Slovenian and Finnish prospective chemistry teachers agree that using particle representations in chemistry education supports students' abstract thinking. The following statements support this conclusion:

“Helps students to understand what ‘chemistry really is’.”

“They make it easier to understand the micro world of substances.”

“It is important to give some insight into what these looks like.”

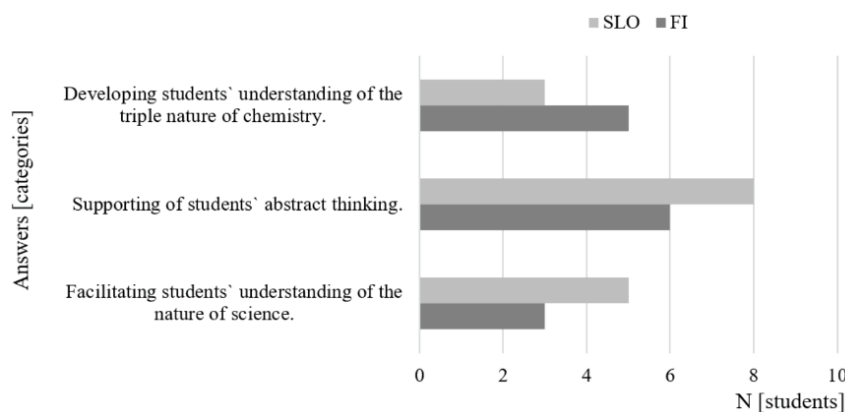


Fig. 7. Prospective chemistry teachers' answers to the question of the role of particle representations in the teaching and learning of chemistry in basic chemistry education.

Both groups of prospective teachers also agree that particle representations facilitate students' understanding of the nature of science. They stated:

“That students can learn the real nature of science.”

“To show the principles of chemistry, as that's how you learn chemistry in high school and universities.”

Both groups of prospective teachers also agree that particle representations develop students' understanding of the TNCC. Some typical answers are:

“This needs to be done carefully.”

“One aspect of contextualised chemistry teaching.”

“More playful than educational, but at later stages the balance shifts to educational.”

These beliefs are in line with the results from another study, which stated that chemistry teachers should implement different types of systems thinking skills, while also helping students in the complex process of their development,⁴⁰ especially regarding understanding chemical concepts, which is quite complex

and demands students' systematic and abstract thinking. In the view of research results,^{19,26,27} the aspects stated by the prospective teachers from both countries are expected. Students at all levels of education express many difficulties in understanding the submicro and symbolic levels of chemical concepts, and using SMRs in teaching chemistry could help to reduce these difficulties. As research indicates,^{30,41–43} the prospective teachers are also aware, that different educational strategies should be used to overcome the gap between all three levels of chemical concepts representations.

The last research question relates to the Slovenian and Finnish prospective chemistry teachers beliefs about students' most common misconceptions of the TNCC. The results show that, in their opinion, students' (aged 13–15) most common misconceptions related to the TNCC that need to be addressed when using SMRs in teaching can be assigned to the following four categories: 1) Misconceptions about atoms, molecules and ions, 2) Misconceptions about the particulate nature of chemistry, 3) How should a chemistry teacher teach? 4) Misconceptions about the state of matter and solubility and 5) Other difficulties.

Fig. 8 indicates that the Finnish and Slovenian prospective chemistry teachers agree that misconceptions about atoms, molecules and ions can occur while using particle representations, as is illustrated by some of their statements:

“Particles don't move, they are coloured.”

“Students think that there are only few ball-shaped particles.”

“Particles appear in different colours than in models.”

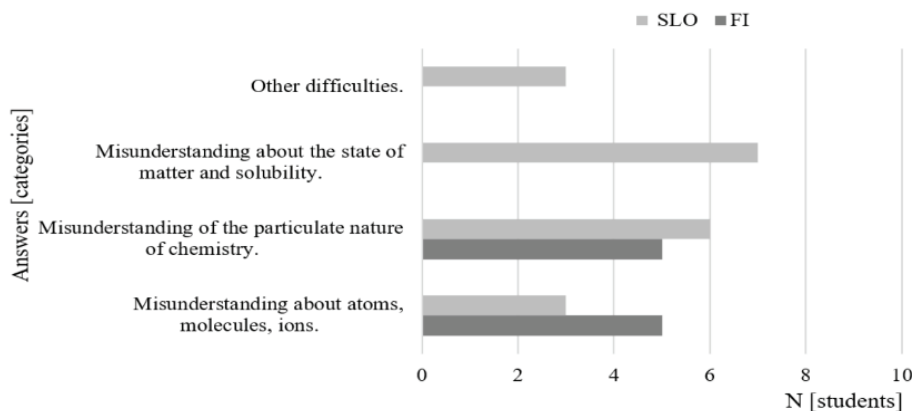


Fig. 8. Prospective chemistry teachers' answers to the fifth question regarding what they believe are students' most common misunderstandings related to particle representations that need to be addressed when using such representations in teaching.

Both groups of prospective teachers believe that misconceptions of the TNCC can appear while using SMRs. Some typical answers supporting this result are:

"That the whole concept is misunderstood."

"Students don't understand that they are only representations to help us understand the phenomenon."

"Understanding that these are representations and simplified models to show some essential aspects of the studied issue."

"Understanding why these are relevant for science."

"Students might think that the models are not only models."

The Slovenian group of prospective chemistry teachers stated that misconceptions about the state of matter and solubility can occur while using SMRs. They noted:

"Showing the wrong distance between the molecules of the solute and the solvent."

"Transitions from solid state to gas state equating a loss of substance."

The Slovenian group of prospective teachers also pointed out some other possible misconceptions related to SMRs that need to be addressed when using such representations in chemistry teaching, such as:

"Problems in drawing schemes."

"Noncompliance with an excess of a chemical reaction in the scheme of the chemical reaction."

"Misunderstandings related to single, double and triple bonds."

Numerous misconceptions regarding the triple nature of chemical concepts have been identified and described in the literature,^{16,21,24} it is encouraging that prospective chemistry teachers in both countries are aware of these possibilities.

Based on their knowledge, the prospective chemistry teachers' described the possible misconceptions about the TNCC that could be developed by students (aged 13–15) with regard to one particular representation (Fig. 3) that was presented to them. Their answers were assigned in the following six categories: 1) Distinguishing between the macro and submicroscopic level in a representation; 2) Distinguishing between representations of the particles; 3) Identifying the misrepresentation of water at the submicroscopic level; 4) Identifying the polarity of sugar molecules; 5) Identifying the lack of a legend; 6) Other.

As can be seen from Fig. 9, most of the Slovenian and Finnish prospective chemistry teachers noticed that the misconceptions of the TNCC could be caused by the poorly prepared SMRs that fail to adequately distinguish between macro and submicroscopic levels of representation. Some typical descriptions by the prospective teachers regarding what can cause the development of misconceptions about solutions include:

"The weird platform-like molecules are hard to understand."

"Water molecules are here and there in something liquid that is not formed from the molecules and these molecules are not interacting with each other."

“Students might think that in water the molecules and the liquid are somehow separated?”

“Students might think that there are water molecules and additionally some blue liquid.”

Some of the prospective teachers of both groups also pointed out that the illustration of polar sugar molecules could cause misconceptions of the nature of polar molecules and what their characteristics are. Some typical answers are:

“The picture gives a bit of a rough view of what polar compounds look like.”

“Students could think that charges have a physical form.”

Both groups of prospective teachers also believe that misunderstanding could develop while learning from SMRs in which it is difficult to distinguish between the representations of a specific particle. A typical answer that illustrates this dilemma is:

“Different atoms have different colours.”

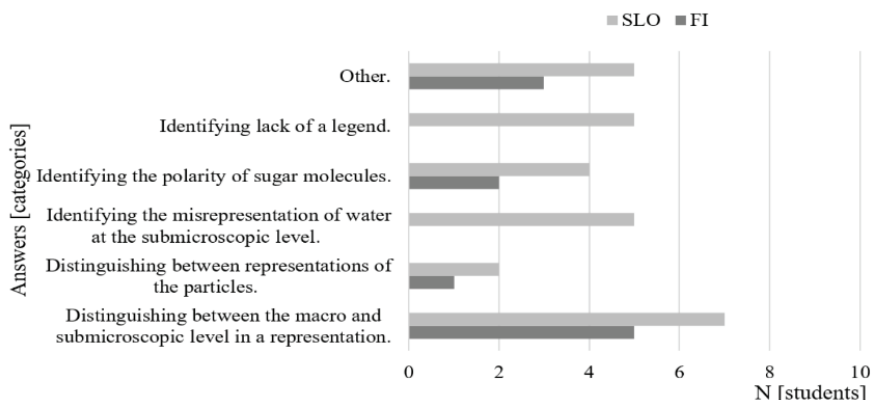


Fig. 9. Prospective chemistry teachers' answers to the question regarding possible misunderstandings they believe could be developed by students based on a particular representation (Fig. 3).

Only the Slovenian group of students pointed out that the representation lacks a legend explaining the specific particle presented in the SMR.

Both groups of prospective teachers pointed out other possible misconceptions that could be formed when using this SMR. Some typical answers are:

“Students may think that these compounds are always symmetrical.”

“The picture represents dissolution process.”

CONCLUSION

The results of this study reveal many parallels between Slovenian and Finnish prospective chemistry teachers' perceptions of their future profession and their understanding of the role of particle representations in learning. The result

is probably linked to the excellent achievements in the chemistry content domain of eighth-graders from both countries in TIMSS 2011⁵⁰ and TIMSS 2015 (Slovenian results, Finland did not participate)⁵¹, as well as in PISA 2015⁵², which are a consequence of many years of effort in the broader chemical education area.

In the study, prospective chemistry teachers in Slovenia and Finland indicated similar reasons for becoming chemistry teachers, emphasising their interest in chemistry and their enjoyment of teaching and communicating about chemistry.

The majority of the prospective teachers from both countries believe that personal characteristics are the most important attributes of good chemistry teachers. They also believe that chemistry teachers should be enthusiastic and use contemporary teaching approaches. The Finnish prospective teachers also highlighted that it is important for chemistry teachers to be interested in students' development.

The majority of prospective chemistry teachers in Slovenia and Finland stated that it is important to integrate particle representations into the teaching and learning of chemistry in basic chemistry education. They believe that the integration of particle representations supports students' abstract thinking and the development of their understanding of the triple nature of chemistry, as well as their understanding of the nature of science.

Prospective chemistry teachers in Slovenia and Finland believe that students' most common misconceptions regarding particle representations are related to misconceptions about atoms, molecules and ions, as well as the incomplete conceptions of the particulate nature of chemistry. The majority of the Slovenian prospective teachers also pointed out the possible alternative conceptions about the state of matter and solubility.

It is also important to emphasise that more effort should be devoted to educating prospective chemistry teachers in the application of contexts in their teaching in lower and higher secondary school chemistry: research shows that learning chemistry through the application of contexts is effective, and that different strategies of the application of real-life problem solving can be used in the chemistry classroom. One such approach is cognitive apprenticeship, as suggested by Putica and Trivic,⁵⁵ which has proved to be effective in secondary school chemistry teaching and learning. A great deal of effort should be put into stimulating and empowering pre-service and in-service chemistry teachers to implement context- and inquiry-based chemistry teaching.^{56,57}

The present study does, however, have certain limitations that need to be pointed out. The main limitation is the relatively small sample of participating prospective chemistry teachers from Finland and Slovenia, despite the fact that the majority of students enrolled in the master's level of chemical education in the 2015/16 academic year participated. In the future, the study could be ext-

ended to also involve first-cycle students. In order to reach more objective analysis of the answers and to collect comparable data and results from students in both countries, the questionnaires for students were in English. It was assumed that most pre-service master teachers from both countries are fluent in English, as also significant proportion of the literature at this level is available in English. However, this could also be regarded as one of the limitations of the study, as students could express themselves easier in their native language.

Additionally, further research should include the development of a more precise profile of the chemistry teacher. This could be developed by applying a more structured questionnaire, supported by in-depth semi-structured interviews. It would be also interesting to compare chemistry teachers' profiles using the same methodology and research problems in other countries that constantly achieve the highest results in international tests of science knowledge (including chemistry, *e.g.*, TIMSS) and in studies of scientific (including chemical) literacy (*e.g.*, PISA).

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ИЗВОД

ПЕРЦЕПЦИЈЕ БУДУЋИХ НАСТАВНИКА ХЕМИЈЕ О ЊИХОВОЈ ПРОФЕСИЈИ: СТАЊЕ У СЛОВЕНИЈИ И ФИНСКОЈ

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Главни циљ овог рада јесте представљање перцепције будућих наставника хемије из Словеније и Финске о њиховој професији и њиховог схватања и представљања улоге тројне природе хемијских појмова (макро, субмикро и симболички) у учењу хемије. У истраживању је учествовало укупно 19 студената мастер студија у области наставе хемије (10 из Словеније и 9 из Финске). Мишљења будућих наставника су прикупљена помоћу електронског упитника са шест питања отвореног типа. Истраживање је показало многе сличности између перцепција будућих наставника хемије из Словеније и Финске у вези с њиховом изабраном професијом и разумевањем улоге тројне природе хемијских појмова, нарочито представљања честичне структуре у учењу хемије. Већина будућих наставника из обе земље сматра да су личне особине најважнији атрибут успешног наставника хемије. Они су високо вредновали ентузијазам наставника за наставу и употребу савремених наставних приступа у хемији. Будући наставници су показали адекватно разумевање улоге тројне природе хемијских појмова у планирању и обради одређене лекције у хемији.

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